PHYSICS IN THE ELEMENTARY SCHOOL.

EXPERIMENTATION in physics in the elementary school has a different meaning from experimentation in physics in the high school. This is especially true where the experiments in the high-school course consist of following a series of minute directions and taking careful note of what happens, either to verify a previously stated law, or with the more vague purpose of being able to generalize the observations into a law. One may well wonder why some books are called "manuals of experimental physics," when not a single chance is given the student to experiment, but only carefully to follow directions and the chain of reasoning indicated by the author. Perhaps it is with this kind of physical experimentation in mind that some teachers of physics in the high school express doubt as to the value of physical experiments in the elementary school.

But the child will experiment. In his play the boy of six tries this and that, in imitation of what he has seen done by his elders. He does not distinguish means from end, or process from result. As he grows older, he is no longer satisfied with the crudity of his playthings, and begins to plan improvements. He notices the ways of doing things, judges their advantages and disadvantages. He notices more and more of process, and acquires the ability to use his past experience in working toward some end; he is able to solve his problem more directly.

In the younger grades, the physics work is a part of the cooking and the textile work, the shop-work, and even the history. The children do not generalize much. Their aims are immediate, and of a purely social nature. They may experiment to find the best way of sailing a toy boat, which they have made while studying the early explorers; or they may try to find a better way of cooking some vegetable, and may suggest a way which they have seen others use. Or, in the smelting of metals, the class may learn something of the temperatures at which the metals melt; but this is only incidental; the work in which they are engaged is the

making of pewter dishes. This work has little of the purely intellectual; the interest is not in the process, but in the doing.

As the children get into the fifth and sixth grades, there is less of the social interest in the experimental work. They begin consciously to see what will happen, but not to see why it happens. Their problems are still concrete, and have to do with things, not ideas and laws. But this last stage is not fully reached before the child has entered the high school, or at least before he is in the eighth grade.

It may be well to suggest some ways in which the different school activities require the aid of physics. Many schools now have gardens, or encourage the children to have home gardens. Before any seeds are planted, the ground must be prepared. Seeds must not be planted before the frost has left the ground, or the seeds will themselves freeze, and the expanding water will rupture the tissues and the seeds be killed. The frozen earth softens slowly, because soil is a poor conductor of heat. The temperature of the soil at different depths, its constitution, its texture, and the amount of water in it, will help to determine the success or failure of the plant. Some plants must be started in a hotbed, where the temperature on a sunny day is higher than in the open air. The problem is raised: How does the water get from the groundwater level to the roots of the plants? And how does the water get from the roots to the leaves of a plant? How and when ought the garden to be watered? The reasons for stirring the soil or not stirring it under different conditions must be understood, and may be worked out experimentally.

The work in cooking requires the frequent help of physical laws, which in their immediate bearing may be worked out by experiment. The problem of how best to apply heat to the food suggests the ways in which heat is transmitted, and the effect of heat on different foods. The problem of solution is introduced in many ways. The expansion of the bubbles of gas in bread or cake when baking brings up problems requiring experiment. The making of ice cream requires some knowledge of freezing mixtures and of the latent heat of water. The use of physical facts in the garden and kitchen is not the result of an effort to correlate

cooking and physics, or gardening and physics, but the relation is natural and free. Physical laws and principles are used to explain and simplify the other work; they are not dragged in just because it is desirable to know them.

The geography classes are constantly experimenting. The problems of the constitution and the activities of the earth are chiefly physical. The percolating waters dissolving minerals and precipitating them; the streams making their channels and carrying their loads to the sea; the atmospheric currents; the different conditions and states of water in the atmosphere, springs, glaciers, volcanoes — all these require experimentation for their appreciation by children. If there were space, it might be shown how physics enters into the work of the "manual-training" classes, or of the clay-modeling and textiles classes. There is always a danger in this kind of work that the problems will not be well enough organized, and that the interest which the child has in simple doing will lead the thought away from the problem. There is a further danger that the problems will not be the children's own, but the teachers'.

But physics deserves more of a place in the curriculum of the elementary school than to be the tool of the other subjects. It has a legitimate place in the course of science in the school, especially in the older grades, along with botany or physiology. In the seventh and eighth grades the children *begin* to think abstractly. The interests begin to shift from things and movements and immediate results to principles, laws, and generalizations. The child begins to think of the *meaning* of phenomena, not so much of the phenomena themselves. Physics adapts itself admirably to these conditions. Yet as the child is only *entering* on the new lines of thought, a good deal of the construction work must be retained, in order that the thinking may be consecutive and logical.

The teaching of a course of experimental physics in the seventh or eighth grade offers also an opportunity of bringing together the physical facts which have been learned in the lower grades. They are brought together from a new point of view, so that they are not thought repetitions by the children. For

example, two or three months may be spent on a study of the principles of elementary machines, starting with the simple lever, and working up to the more complex combinations. The principles of the lever, the wheel and axle, the pulley and the inclined plane, may all be familiar, but the child has never consciously formulated the laws or principles, and fresh experimentation is necessary. This reason for experimenting is a distinct gain on that of former years, when the process or the immediate end constituted the problem. An excellent way to apply the laws formulated is to construct a piece of apparatus which combines many of the principles of machines, such as a clock, or one of the numerous mechanical toys.

It may be wise to take up a problem with many new factors, such as that of light. The fact that many of the children are interested in photography offers an introduction to the subject, and suggests a way of attack and a point of view. The knowledge gained of the nature of light, the laws of reflection and refraction, the uses of lenses of different kinds and of different focal distances for different purposes, may be summarized by the use of cameras by the class, or even by the construction of simple pinhole cameras.

Classes are always interested in the study of electricity. It is usually found that the children are familiar with the fundamental facts about electricity, and a review of these suggests problems to the class. The question of what is going on in the electric cell requires experimentation to answer, and experimentation consciously planned toward a rather remote end, where the conditions must be varied or simplified to bring out the answer. A search for a theory of electro-magnetization requires repeated trials or experiments before theories are found to match with facts. The problem of the chemical effects of the electric current requires experiments which bring out the principles of electroplating and the storage battery. Toward the end of the course, the class takes delight in constructing pieces of apparatus which apply the laws of electrical action already learned. It is entirely practicable for all the members of the class to construct, or at least put together, apparatus which has some real value. It is

possible for classes to make storage batteries, dry cells, electric stoves, electro-magnets, induction coils, to assemble the parts of motors, and the parts of electric bells, besides making elaborate carbon-zinc batteries. The value of this construction work lies in the spirit of investigation which the child acquires in attacking his *own* problems, rather than in the manual skill attained.

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